LOW EMI WITH HIGH MECHANICAL STRENGTH METHOD OF CONNECTING SIGNAL CONNECTORS

Inventor(s): Branislav Petrovic

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to methods of physical connections of signal connectors in electronic devices, and more specifically to electrical connections of signal connectors to printed circuit boards (PCBs), with emphasis on low cost connections of surface-mount (SMT) connectors to PCBs signal lines, providing high mechanical strength and low electromagnetic interference (EMI), i.e. low unwanted radiated emissions and low susceptibility to unwanted signals.

Background of the Related Art

Most electronic devices require some type of electrical interconnections with other devices. Often, the interconnection is accomplished by the means of an electrical cable with signal connectors at both ends, each end connected to the respective device. If the interconnect cables and all connection points to signal lines are not shielded properly and other precautionary measures taken, the interconnect cable can potentially become an antenna, causing EMI (unwanted radiated and/or conducted emissions, as well as unwanted signal ingress/interference problems). Examples of EMI sources are radio frequency (RF) interconnects between various devices via RF coaxial connectors and cables, or high-speed digital signals carried over twisted pairs.

Electromagnetic (EM) fields are generated by the flow of electric currents. According to electromagnetic theory, any EM field will have a tendency to radiate (i.e.

to propagate in the medium away from the source), unless it is confined, or reduced to zero (for instance, through cancellation by an opposing field of the same intensity, generated by an equal current flowing in the opposite direction). In other words, any non-zero EM field will propagate away (radiate), if there is no obstacle to prevent it. By reciprocity, reception (ingress) of EM fields will occur in similar conditions. Luckily, even if the field is not completely cancelled, it is still possible to prevent radiated emissions, by preventing this residual EM field to freely propagate. This can be accomplished by confining the field inside a shielded environment, such as in an enclosed metal shield. However, preventing the residual field from occurring in the first place, rather than confining it, is a better way of coping with EMI problems.

An example of a case where an EM field is not cancelled, is in a coaxial cable carrying a current on the outer shield, without having a return current flowing in the inner (center) conductor in the opposite direction. This can occur if EM fields exist in the vicinity of the cable (for instance, generated by currents flowing in nearby circuits). Often, this condition exists in the exit/entry points of signal cables. The flow of the outer shield currents, not being cancelled by the inner conductor currents will, as mentioned above, result in unwanted signal radiation and/or signal pick-up.

Thus, a particularly important aspect of EMI prevention is the shielding of the exit/entry points of cables from/into devices, which is the focal point of this invention.

In addition to EMI, another aspect to consider when dealing with electrical connections to PCBs is the mechanical strength of these connections, i.e. the ability to withstand physical forces exerted on cables and/or connectors. These forces are normally encountered during cable mating, handling or shipping, and often with installed cables in operation, due to insufficient strain relief. The consideration of mechanical strength is of particular importance in conjunction with surface-mount

connectors, which exhibit much less strength than their through-hole counterparts. SMT connectors, when installed on the PCB, have poor mechanical strength in respect to radial (lateral) forces.

In the prior art, a widely used solution to address the cable exit/entry EMI problem is illustrated in FIG. 1., where an electronic device 10 in a metal enclosure 30, equipped with an RF coaxial connector 40 for signal connection is shown. An EMI "O - Ring" gasket 110 is employed here to prevent EMI. For the purpose of analyzing the EMI conditions, let's assume that this gasket is not installed in FIG. 1. In this case, when a coaxial cable (not shown in the figure) is mated with the connector 40, the EMI problem will likely occur, for the following reason:

A micro-strip transmission line 50, which carries a current transmitted by a signal source 60 (e.g. a transmitter amplifier), due to incomplete cancellation of the EM field it carries, will generate a residual EM field in the vicinity of RF connector 40 and a mated coaxial cable (not shown). This EM field will induce currents in the outer shield (but not in the inner conductor) of the mated cable. The current in the outer shield, not accompanied by the opposite current in the inner conductor will give rise to EMI radiation. By reciprocity, the transmission line 50 may become a victim of unwanted external signal pick-up, carried into the unit by the outer shield of the cable. This may be particularly important if device 10 is a signal receiver (in which case device 60, instead of being a signal source as in the above transmitter example, may be a high gain input amplifier), where the picked-up signals can interfere with reception of desired signals.

The reason for the above mentioned incomplete cancellation of the EM field in the micro-strip transmission line is well known in the art – it is due to the micro-strip's asymmetrical conductor geometry and it's inhomogeneous dielectric. A good

description and analysis of this matter can be found in the reference: K. C. Gupta et al.: "Microstrip Lines and Slotlines"; Artech House, Inc., 1979, pp. 2 – 4. , a brief interpretation of which is summarized here:

> One conductor of the micro-strip line 50 is a piece of copper trace (top side) 52 of a certain (typically small) width, and the other conductor is a ground plane (bottom side) 130, which is typically much larger – wider – than top trace 52. One part of the EM field resides inside the dielectric of board 20, and the other part in the surrounding air. Due to differences in conductor widths and dielectric constants of the two media, the two parts of the EM field have different intensities. Having different intensity, the part of the EM field generated by the current in top trace 52 cannot be completely cancelled by the counterpart field generated by the ground-plane return current. The resulting residual field in the vicinity of the top trace causes unwanted signal radiation and/or signal pick-up, and is the main downside of micro-strip lines. However, in spite of this deficiency, due to ease of implementation in PCBs and associated low cost, micro-strip geometry is widely used as a transmission medium for signal carriage in many electronic devices.

As mentioned above, an EMI "O - Ring" gasket 110 is employed in the prior art to help confine the field inside the shield 30 and reduce the EMI. There are several shortcomings with this approach.

First, the EMI gasket's electrical contact, and therefore the shielding efficacy, relies on the mechanical force exerted upon the gasket 110 by the top cover of shield 30. This force must be maintained indefinitely, under all operating conditions. The gasket itself must be made out of shape-conforming materials, such as conductive

polymers or compressable wire-mesh materials. These materials typically have inferior electrical conductivity, i.e. shielding efficacy, compared with metal conductors. Long term shielding quality of such gaskets is also questionable, because in time the elasticity of such materials may degrade, causing degradation in the quality (conductivity) of the contact and consequently loss of shielding efficacy. Second, corrosion may occur with wire-mesh gaskets, potentially further aggravating the problem in time. Third, the aspect of mechanical weakness of SMT connectors is not addressed in the prior art. As can be seen from FIG. 1, connector 40 is secured to PCB 20 by a solder joint 90 between the connector's body 80 (which also serves as a ground connection), and the PCB 20, as well as with solder joint 100, between the connector's center conductor 70 and the PCB 20. This construction is clearly weak in radial direction – only adhesion forces between the copper clad and the board, and the strength of the copper foil itself offer any resistance to a lateral force exerted on the connector. A lateral force exerted on the connector can cause tearing and peeling-off of the copper, leading to catastrophic failure.

This weakness is specific to surface mount connectors only, in contrast to through-hole connectors. The through-hole connectors have pins protruding through the PCB holes, providing much higher lateral strength, and as such would be a better choice than SMT connectors. The mechanical weakness of SMT connectors can pose operational risks of connector failures induced during cable mating and/or cable manipulation operations and ongoing strain due to the weight of the cable pulling on the SMT. However, in spite of this deficiency, SMT connectors are still a preferred choice, due to strong trends in manufacturing of electronic devices towards SMT-only processes.

Other related references include U.S. Patent No. 4,827,378 to Gillan et al., issued May 2, 1989.

SUMMARY OF THE INVENTION

It is one objective of the method of the present invention to provide EMI performance improvements of the physical connections of signal connectors to printed circuit boards over the prior art.

It is another objective of the present invention to increase the mechanical strength of SMT connectors, particularly in respect to lateral forces.

It is further an objective of the present invention to achieve the above improvements in a way simple and easy to design and implement.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side cross-section view of an exemplary electronic device, illustrating the prior art solution of micro-strip line to coaxial connector transition, where unwanted radiation/reception of signal(s) is reduced by the means of an EMI gasket installed around the signal connector.

FIG. 2 is a side cross-section view of the exemplary electronic device, illustrating the present inventive solution of a micro-strip line to coaxial connector transition, where unwanted radiation/reception of signal(s) is reduced or completely eliminated by means of an auxiliary printed circuit board, which serves both as an EMI shield, and at a same time provides additional mechanical strength to surface-mount connectors.

FIG. 3 is a top view of the exemplary electronic device, with removed signal connector, showing features and patterns on the main printed circuit board, required for the present inventive solution of a micro-strip line to coaxial connector transition.

FIG. 4 is a top view of the exemplary electronic device with details of the present invention, showing the features of the auxiliary printed circuit board and details of the connections with the coaxial connector, the main printed circuit board and the metal enclosure.

DETAILED DESCRIPTION OF THE INVENTION

The present invention utilizes the advantages of well-known strip-line geometry over micro-strip geometry as a transmission media for carriage of electrical signals. The strip-line is constructed in a way similar to the micro-strip line, except it has an additional ground plane layer on top of the signal trace. It is well known in the art that the additional ground plane ensures complete confinement of the field inside the structure of the strip-line, consequently ensuring complete elimination of the field outside of the structure.

The solution to both the EMI problem and mechanical strength problem in the present invention is achieved by constructing a strip-line structure around the connector and around the signal feed line, as illustrated in FIG. 2. An auxiliary structure, composed of two conducting surfaces with an insulator sandwiched in between them can be used to accomplish this goal, by placing the structure above the micro-strip transmission line 50 and around the connector 40. A preferred embodiment of such a structure is in a form of an auxiliary printed circuit board 150, serving as a top ground plane to form a strip-line structure, and at the same time reinforcing the lateral mechanical strength of the connector 40. The auxiliary PCB 150

is installed around connector 40 and atop micro-strip line 50, and is secured, and grounded to main PCB 20 by means of solder joints 160 and 180, and via solder joint 170 both to the metal enclosure 30 and to a topside ground 190 (see FIG. 3), with further connection to the bottom side ground plane 130 via plated-through holes 140. The metal enclosure 30 is grounded to the topside ground plane 190 via solder joints 120 and 170, and further to the bottom side ground plane 130 via plated-through holes 140. This way, an effective closed shield (or cavity), grounded to a main circuit ground is formed around connector 40 and micro-strip transmission line 50, ensuring confinement of the EM field and consequent reduction or elimination of EMI. Connector 40 is also soldered to joint 160, which in conjunction with auxiliary PCB 150 provides additional shielding, as well as lateral mechanical strength to the connector.

Besides EMI and mechanical strength improvements, the present invention provides an additional value, and that is the means to control the matching of the electrical impedance of the signal line 50 to the load (or source) impedance connected to connector 40. Unlike other shielding methods, which often adversely affect the line impedance by "detuning" the line by some closely spaced conductive shield element(s), the present invention's well defined strip-line geometry can be taken advantage of to yield a desired, well matched line impedance. It is well known in the art that the characteristic impedance of a strip-line is determined by it's geometry, namely by the width of the line, and the height of top and bottom ground planes (i.e. the thickness of the boards), as well as by the dielectric constant of the medium. By designing the geometry and features of both the main and auxiliary PCB lines and grounds, using standard strip-line synthesis methods, a desired impedance can be

achieved (for example most common impedances of 50 or 75 Ohm), ensuring efficient power transfer between the source and the load.

Description of some of the construction details follows:

The copper patterns and other features on the main PCB 20 underneath the auxiliary PCB 150 are depicted in FIG. 3 (with signal connector 40 and auxiliary PCB 150 removed). The micro-strip line 50 terminates in end-point 55 of the copper trace 52, to which center conductor 70 of connector 40 connects. The copper on the topside of PCB 20 around micro-strip line 50 is etched away (210). Topside ground plane 190 (with etching edge 200) is connected to bottom side ground plane 130 by means of plated-through via holes 140.

The top view of the features of the auxiliary PCB 150 and details of the connections with the coaxial connector 40, the main PCB 20 and the metal enclosure 30 is shown in FIG. 4. The copper at the bottom side of the auxiliary PCB is a ground plane, part of which is etched away (220) and is located on top of the counterpart 210 on the main PCB. Edge 230 of the etched-away copper 220 coincides with its counterpart edge 200 on the main PCB. The topside of auxiliary PCB 150 is also a ground plane, which is connected to bottom side ground plane of this board by the means of plated-through via holes 145 The auxiliary PCB has a cut-out opening 250, in order to accommodate the connector 40, shaped to tightly sit around connector's body 80, for good mechanical and electrical fit. The auxiliary PCB 150 is also equipped with plated-through holes 240, cut in half ("half-moon holes"), which serve the purpose for soldering to the main PCB, via solder joints 180.

It is important to note that the quality of shielding depends on how well the EM field is confined, or "sealed" inside the cavity, i.e. how much of the field "leaks"

out of the cavity. This, in turn, depends on how well, or how "tight" are all relevant "seams" sealed. By inspecting FIG. 3 and FIG. 4, it is not difficult to find that the "seams" in question here are namely the solder joints and the ground vias. The spacing amongst the adjacent solder joints as well as amongst the ground vias is the key factor controlling the efficacy of shielding. The closer, or "denser" they are, the better the shielding. The measure of density is relative, and must be viewed in respect to the wavelength of the carried signal. Whether the spacing is dense or not must be judged in comparison to the wavelength of the signal. The rule of thumb is that the spacing between the two adjacent ground points of the shield must be a very small fraction of the wavelength, typically less than one percent, in order to effectively block the field passing through the shield. For example, a 1 GHz signal, having a wavelength of about 200 mm in an FR4 PCB, would require ground points density of about 1 mm for effective EMI shielding. When the density of the ground points is high enough (i.e. the spacing small enough) to nearly completely stop the field, the "seams" can be deemed "continuous" for all practical purposes. Ideally, for maximum shielding, both the solder joints and vias should be made as "continuous" as possible in this sense.